JET NOISE RESEARCH AT NASA

Brenda Henderson, NASA

NAVAIR Noise Workshop
December 10, 2008
Patuxent River, Maryland

A presentation outlining current jet noise work at NASA was given at the NAVAIR Noise Workshop. Jet noise tasks in the Supersonics project of the Fundamental Aeronautics program were highlighted. The presentation gave an overview of developing jet noise reduction technologies and noise prediction capabilities. Advanced flow and noise diagnostic tools were also presented.

Jet Noise Research at NASA

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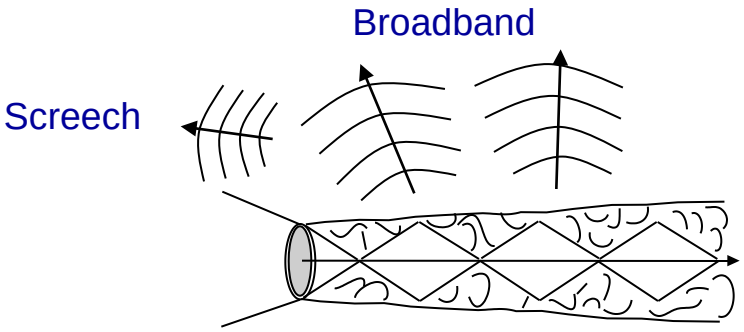
Fundamental Aeronautics Program

- Four projects
  - Supersonics
  - Subsonic Fixed Wing
  - Subsonic Rotary Wing
  - Hypersonics
- Supersonics Technical Challenges
  - Efficiency
  - Environment
    - Airport Noise
      - Prediction
      - Diagnostics
      - Engineering
    - Sonic Boom
    - High Altitude Emissions
  - Performance
  - Entry, Descent, and Landing
  - Multidisciplinary Design, Analysis, and Optimization

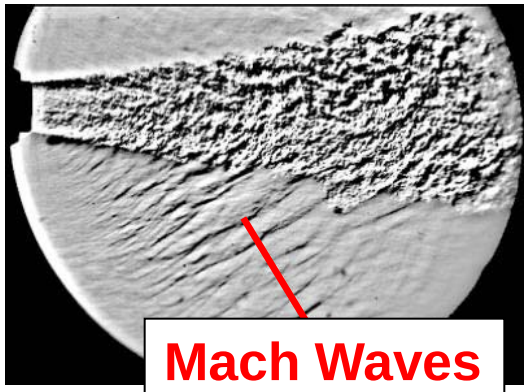
Critical Military Jet Noise Sources

Shock Noise



Mixing Noise

- Mixing noise
- Mach wave radiation
  - Crackle
- Shock associated noise
  - Broadband
  - Discrete
- STOVL noise/tones



Courtesy of D. Papamoschou

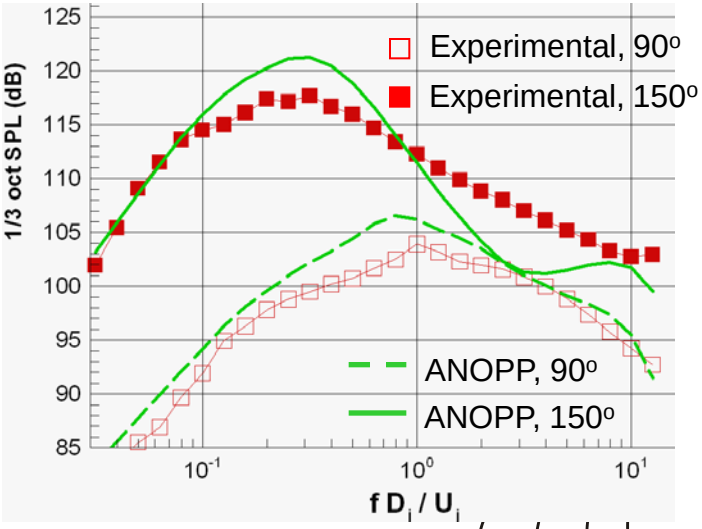
Modeling and noise reduction technology must address each of these differently depending on flight regime

Prediction

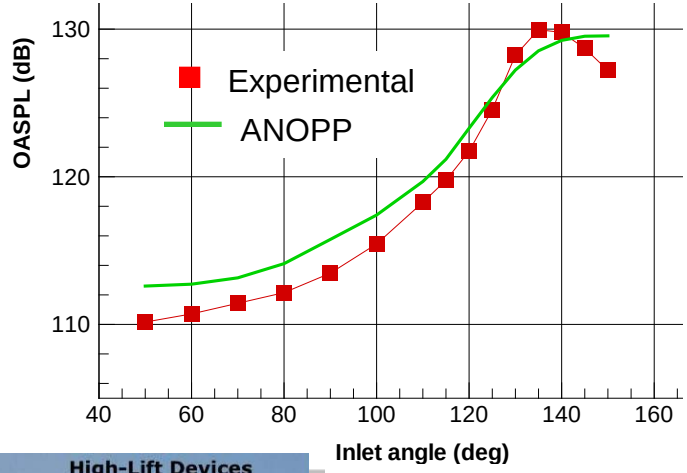
NASA Aircraft Noise Prediction Program: ANOPP

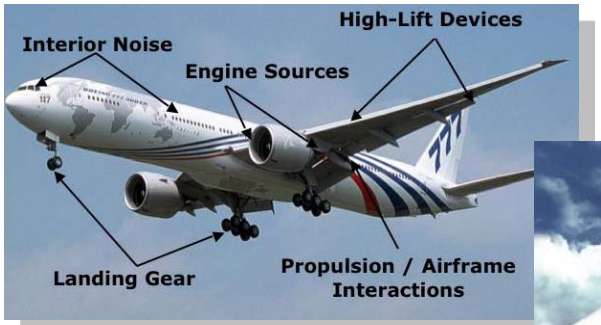
NASA POC: Casey Burley, Casey.L.Burley@nasa.gov

- **Total aircraft noise prediction capability for subsonic and supersonic aircraft.**
  - Predicts aircraft source noise, propagation and impact at receiver
  - Predominantly semi-empirically based methods
  - Ability to predict high speed jet mixing & broadband shock noise



$M_j = 1.2$
$TT_R = 3.6$
BPR = 0.2





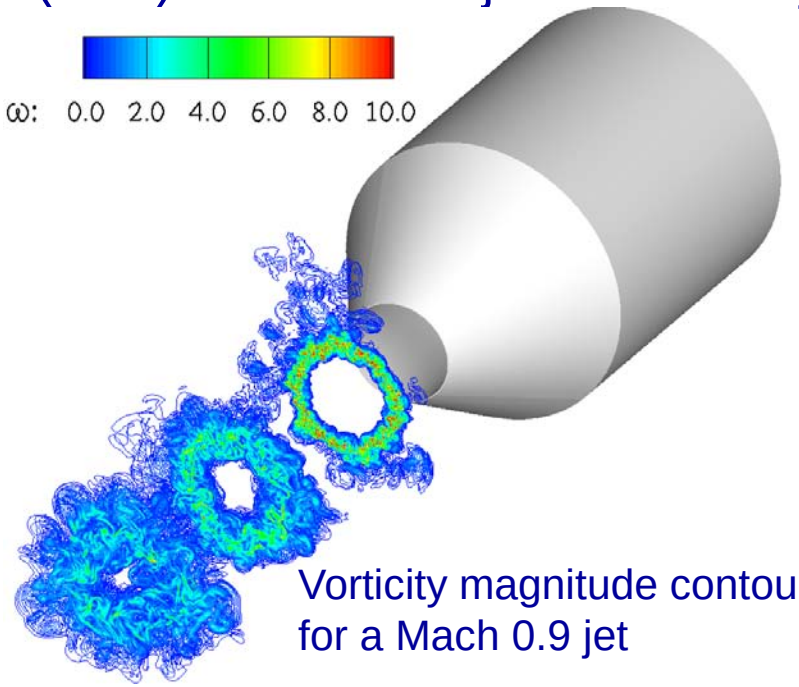
Receiver ← **Propagation** ← **Source**

Large-Eddy Simulation Research

NRA: Stanford University

PI: Sanjiva Lele

- Code development for time-dependent turbulent simulations of flowfields from noise suppressing nozzles
- Develop computational tools to couple Reynolds Averaged Navier-Stokes (RANS) and Large-Eddy Simulation (LES) methods for jet noise analyses.

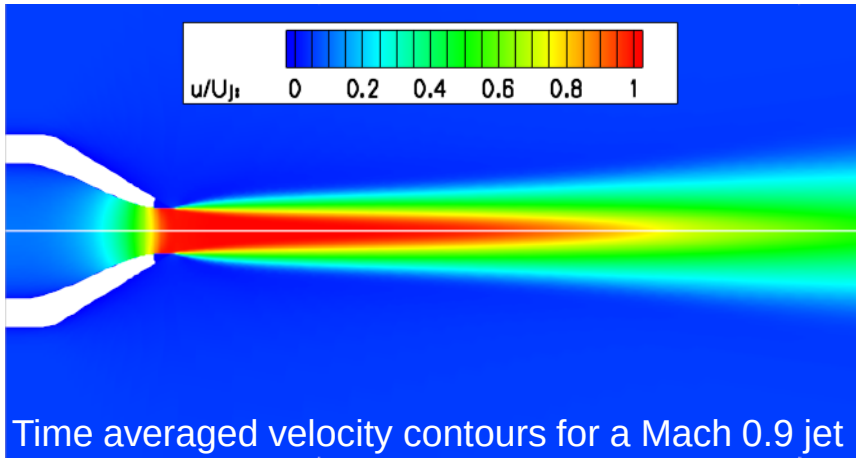


Vorticity magnitude contours for a Mach 0.9 jet

NASA POC: Jim DeBonis

James.R.Debonis@nasa.gov

- In-house research code
- Low dispersion Runge-Kutta time stepping (1st - 4th order)
- High-order (2nd - 12th) central and DRP based spatial schemes
- Shock capturing filters

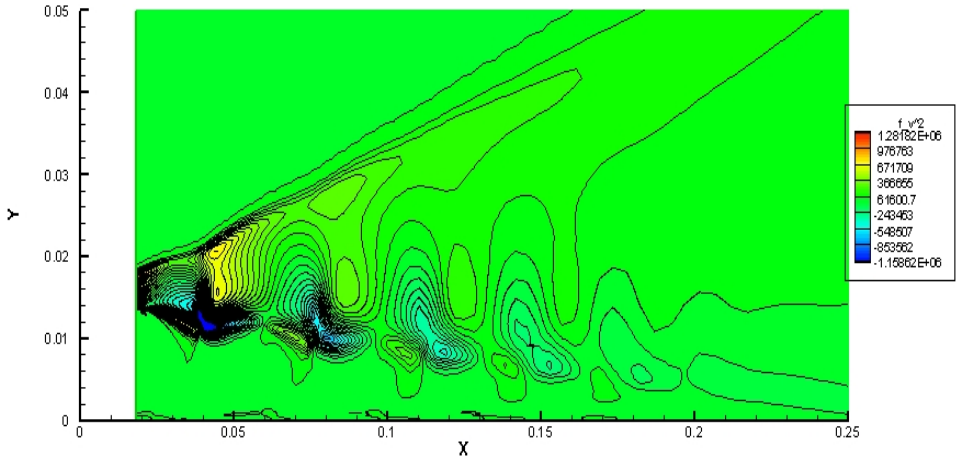


Time averaged velocity contours for a Mach 0.9 jet

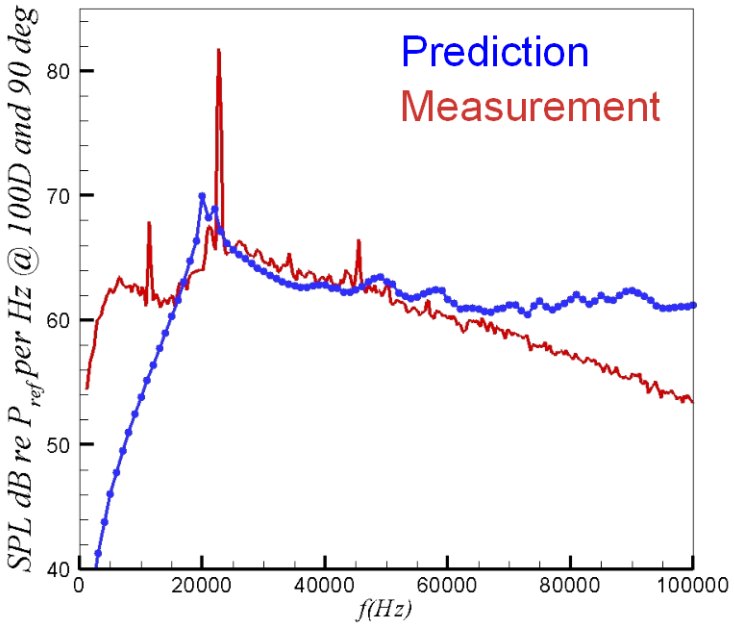
Broadband Shock Associated Noise Prediction

NRA: Pennsylvania State University, PI: Philip Morris

Source Strength Distribution



Far Field Radiated Noise Spectrum



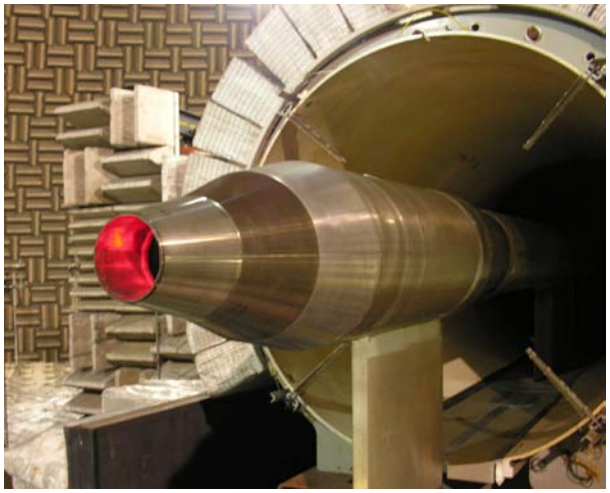
- Noise model based on RANS CFD prediction for shock cell structure and on model for two-point turbulence statistics
  - Captures observed trends – reviewing details of turbulence source statistics to improve high frequency predictions
  - Requires ~1 hour per observer angle to compute

Improving Scale Model Noise Prediction

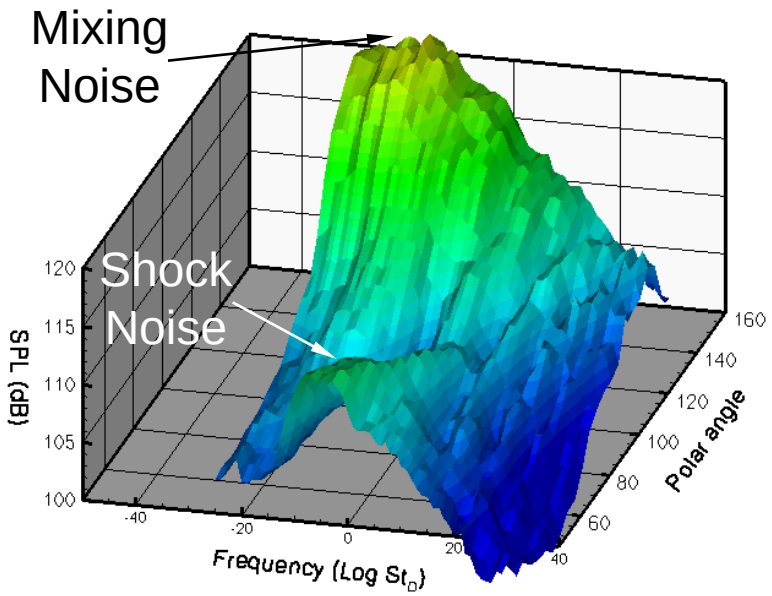
Funded by Strategic Environmental R & D Program (SERDP)

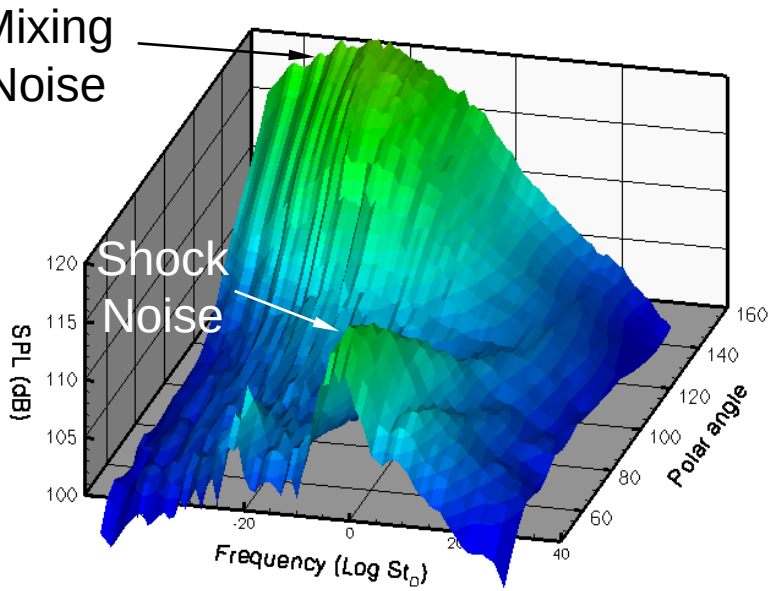
NASA POC: Tom Norum, Thomas.D.Norum@nasa.gov

F-15 ACTIVE Flight Test (1997)



Moderate Scale Tests



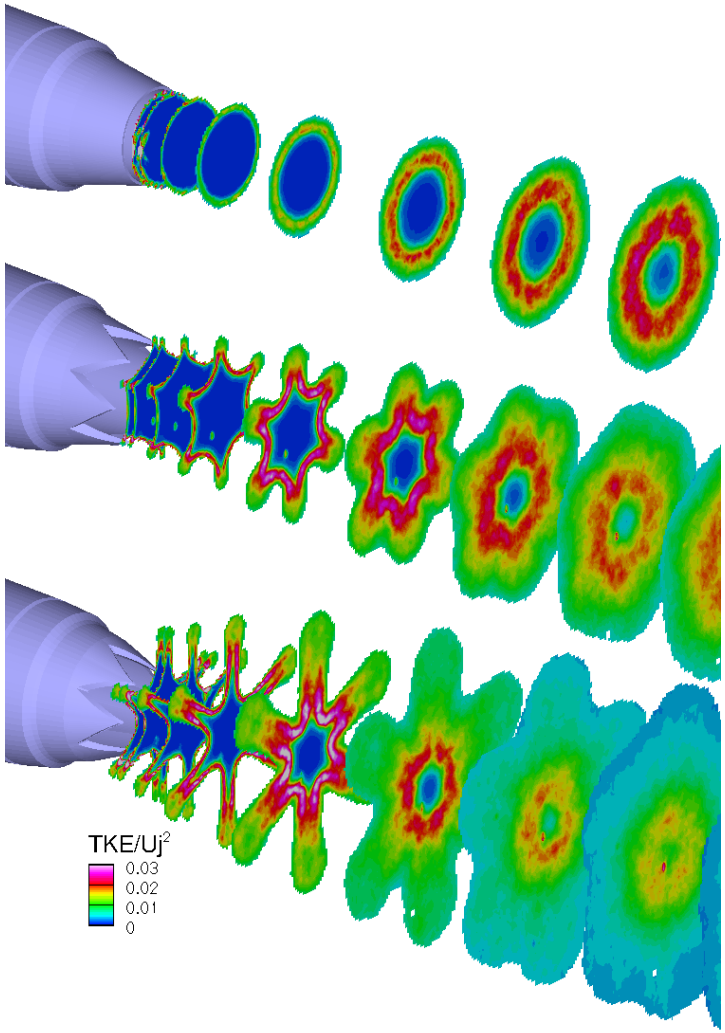


Diagnostics

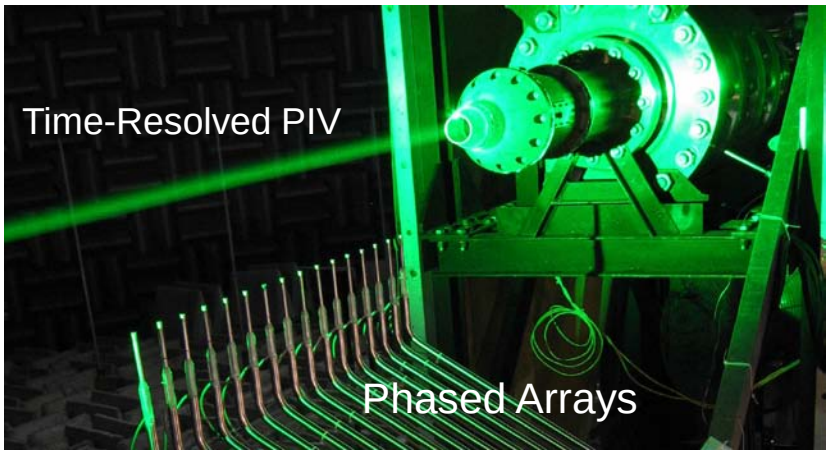
Advances in Flow Diagnostics for Noise Reduction and Prediction

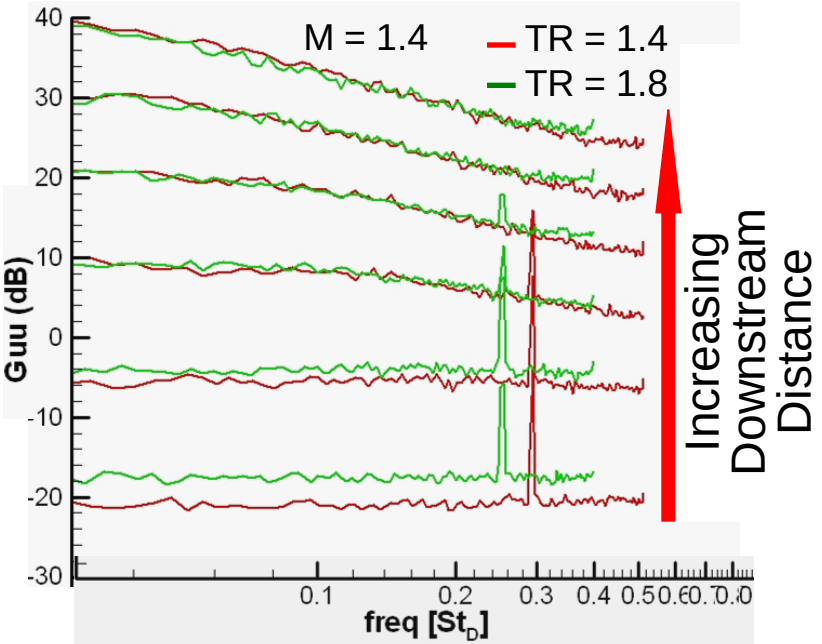
NASA POC: James Bridges, James.E.Bridges@nasa.gov

Turbulence measured in hot jets using Particle Image Velocimetry (PIV)



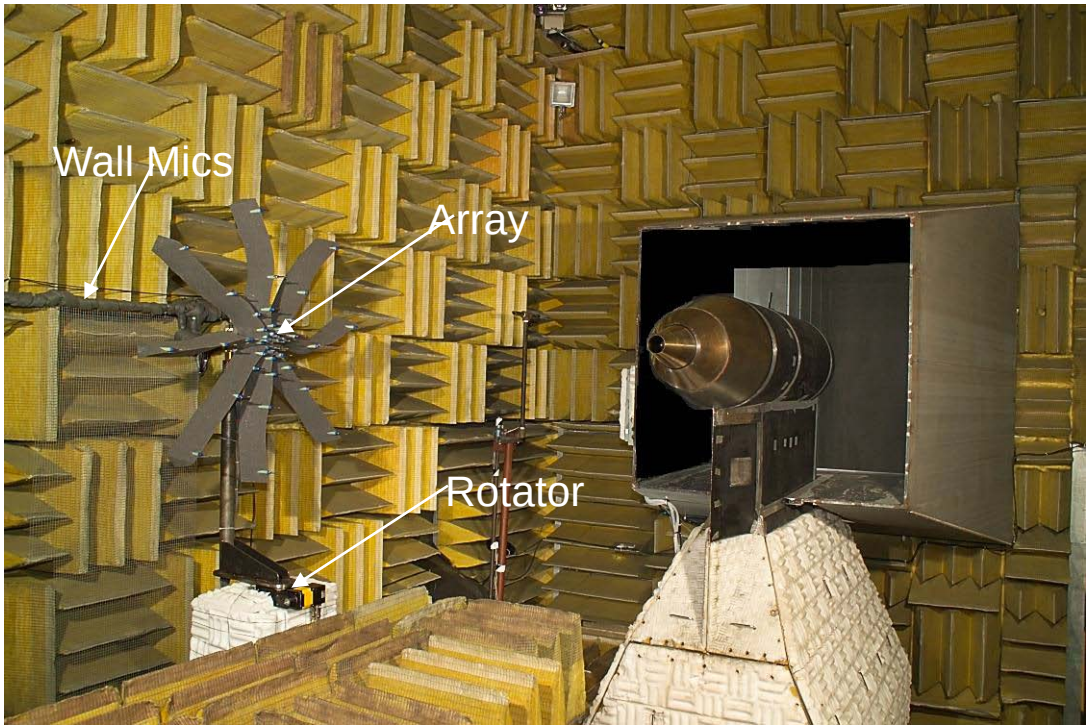
Flow-Source correlations explored using multiple advanced techniques





JEDA Measurements for Jet Noise

NASA POC: Tom Brooks, Thomas.F.Brooks@nasa.gov



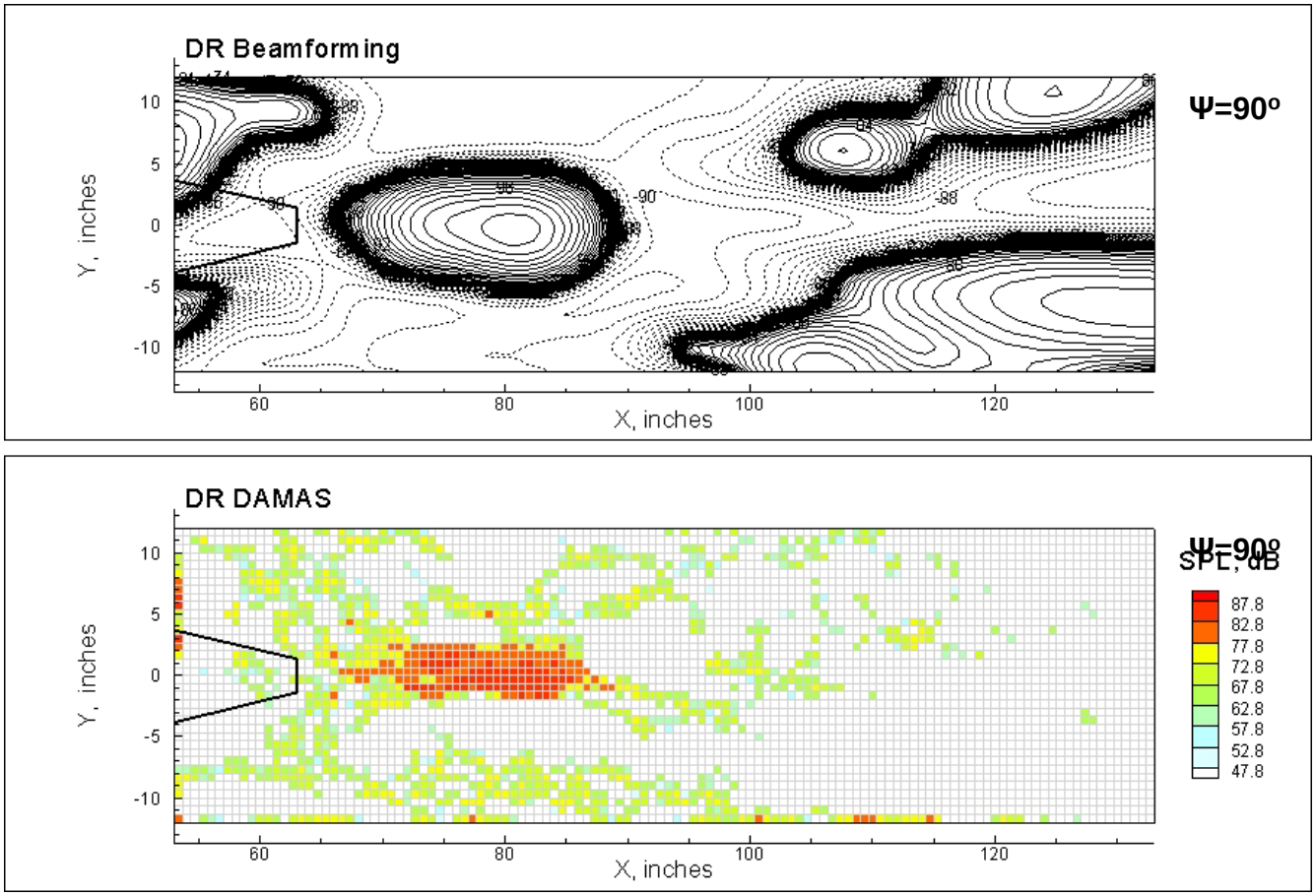
Array Installation

Goals:

- Develop processing methodologies for incoherent and coherent convecting sources
- Characterize performance of array
- Obtain detailed source distribution maps for subsonic and supersonic exhausts
- Obtain data for validation of prediction codes

Supersonic Measurements with JEDA

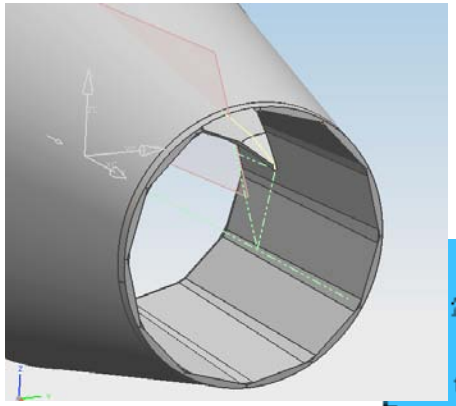
Convergent / Divergent Nozzle, NPR = 2.27, M_j = 1.15, $f_{1/3}$ = 12.5 kHz



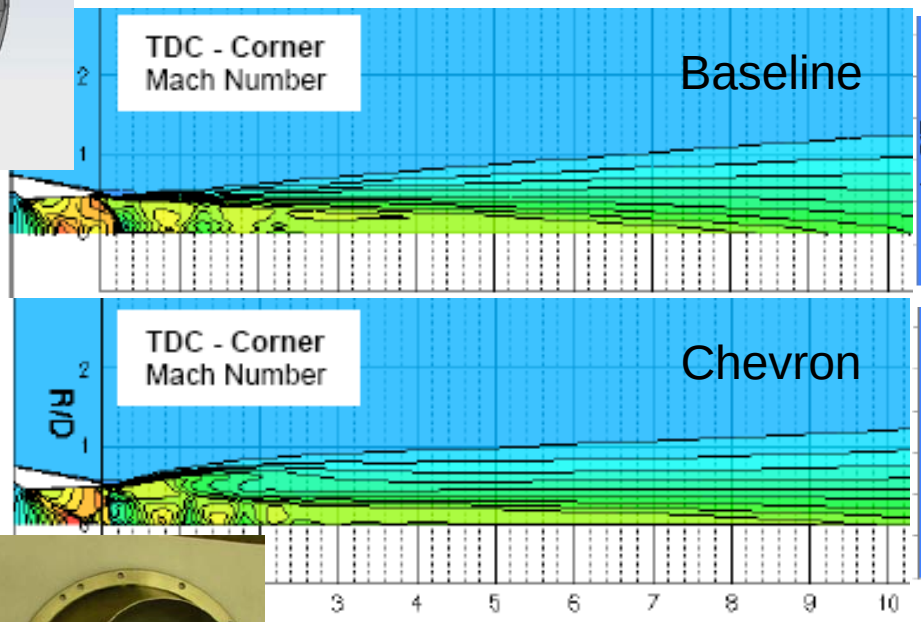
(Non-coherence assumption DAMAS processing – preliminary results)

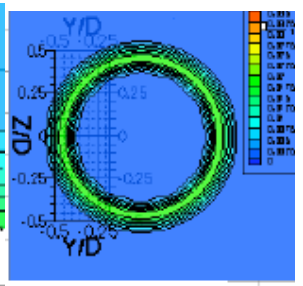
Engineering

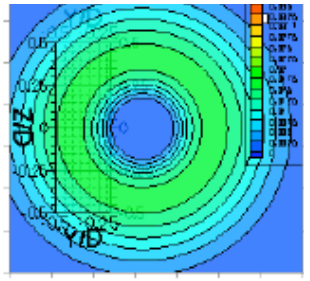
Mechanical Chevrons for Noise Reduction

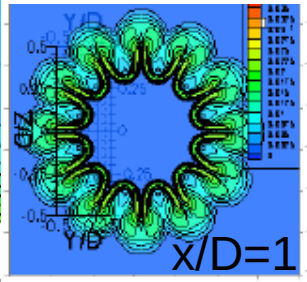


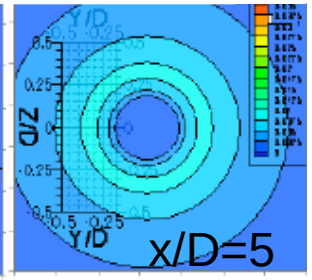
Funded by Strategic Environmental R & D Program (SERDP)
NASA POC: Tom Norum, Thomas.D.Norum@nasa.gov











Investigate impact of nozzle geometry and chevron parameters on radiated sound

Supersonic Jet Noise Suppression Using Plasma Actuators

NRA: The Ohio State University
PI: Mo Samimy

- Various jet instabilities are manipulated to mitigate noise
- Large Eddy Simulations used to predict optimal jet forcing for noise mitigation

Example of actuation effects on the jet flow field

Image of baseline Mach 1.3 jet

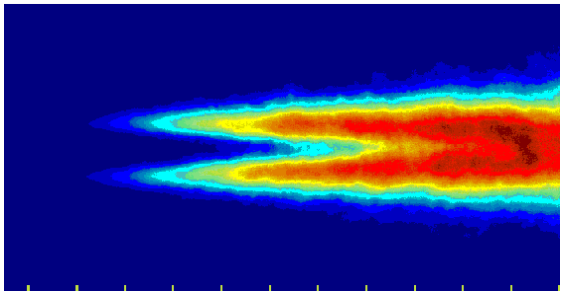
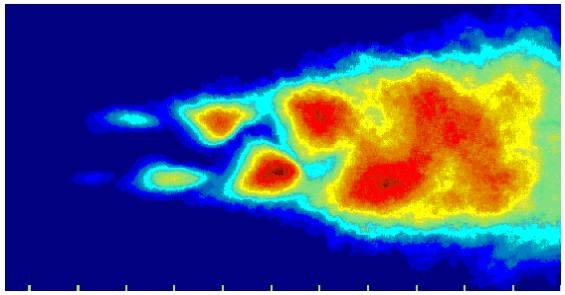
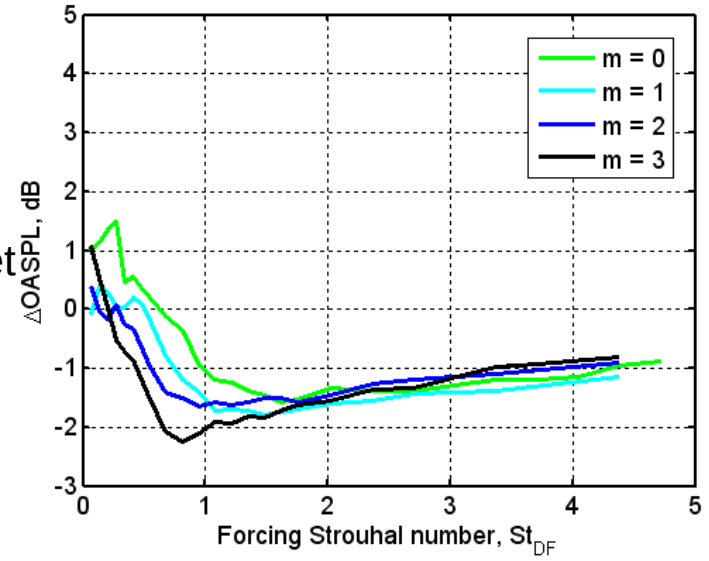


Image of forced jet at 5 kHz and at azimuthal mode m= 1



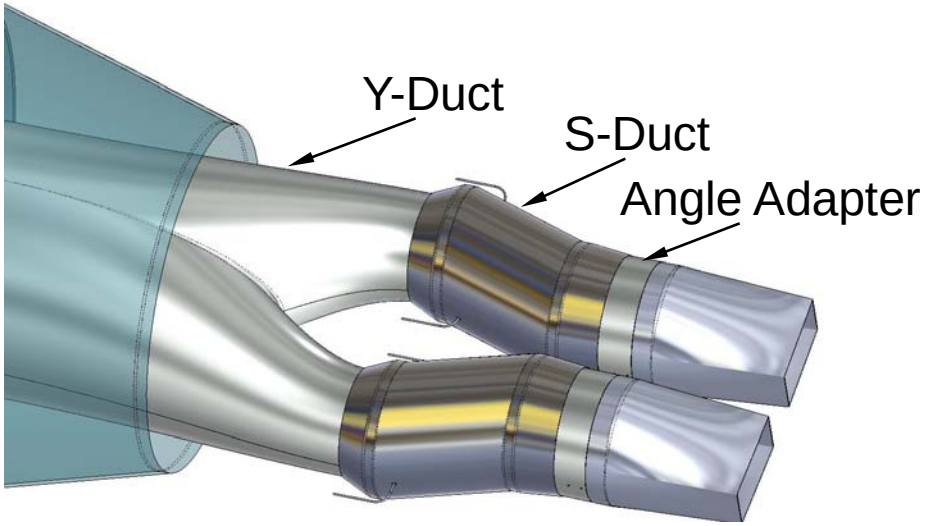
Example of noise mitigation at Mach 1.3

Noise reduction relative to baseline jet (actuation not optimized)



Twin Model for Jet Interaction Studies

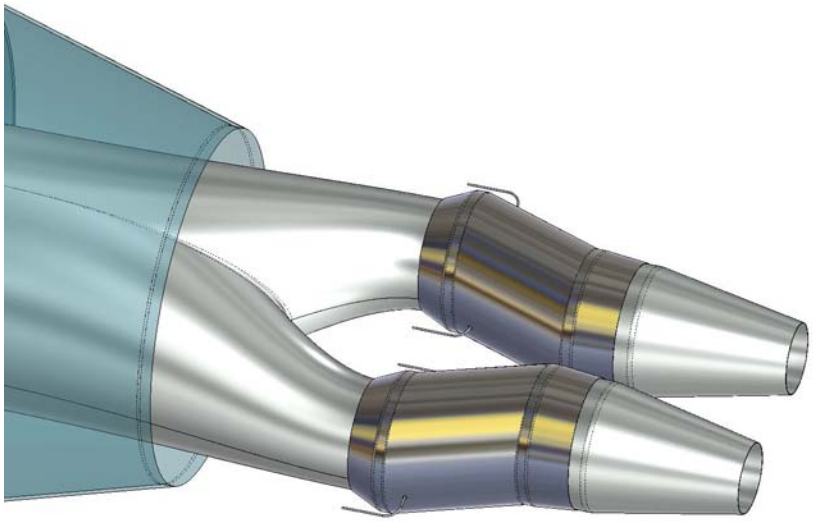
NASA POC: Brenda Henderson, Brenda.S.Henderson@nasa.gov



Investigate

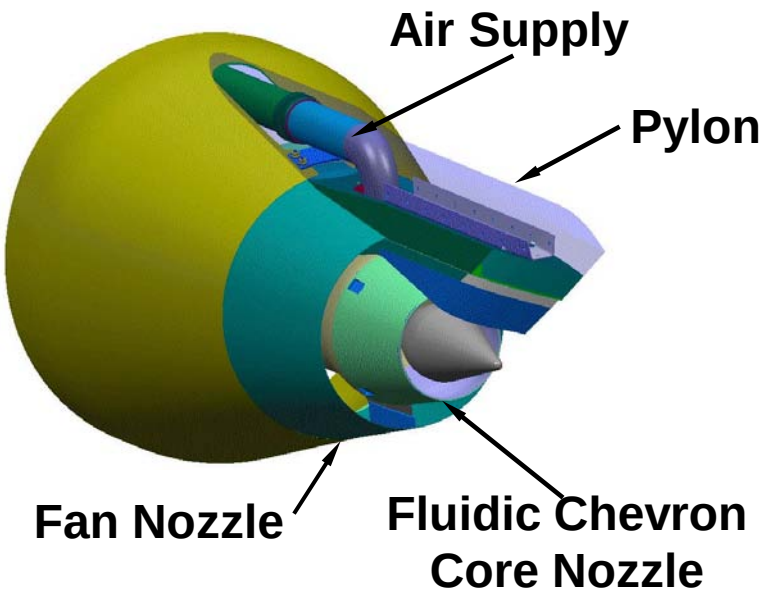
- Jet plume interactions
- Noise characteristics of rectangular nozzles

- Critical design review - Dec. 11
- Model delivery - March, 2009



Fluidic Chevrons for Noise Reduction

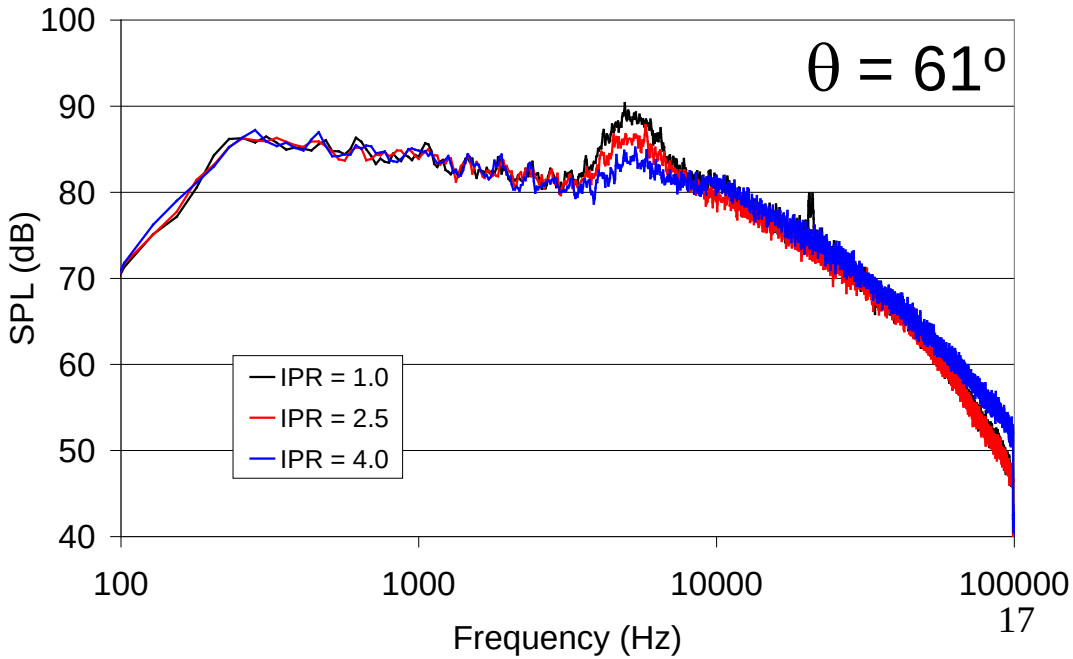
NASA POC: Brenda Henderson, Brenda.S.Henderson@nasa.gov



- Air injection nozzles tested at subsonic and supersonic exhaust speeds
- Mixing noise and broadband shock noise reductions achieved for some configurations and operating conditions
- Nozzle design resulted from partnership between NASA and Goodrich Aerostructures

$NPR_c = 1.61$

$NPR_f = 2.23$



Developing Technology Summary

- Prediction
  - ANOPP
  - LES
  - Statistical models for broadband shock noise
  - Scale model and flight data databases
- Diagnostics
  - PIV
  - Time accurate PIV
  - Phased array
- Engineering
  - Chevrons
  - Plasma actuators
  - Twin jet studies
  - Fluidic injection